APPROVAL SHEET FOR SUSPENDED LOAD OPERATIONS

SLO-KSC- 1993-008

TITLE Aft Booster Set Down on the Mobile Launch Platform Hold Down Posts Using 325-Ton Crane

DOCUMENT NUMBER/TITLE OMI B5303 - Stacking and Alignment Operations

PREPARED BY Malcolm Glenn

DATE 2/18/99

REQUIRED APPROVAL

CONTRACTOR ____ DESIGN ____ R & QA ____ OPERATIONS ____ SAFETY

NASA ____ DESIGN ____ R & QA ____ OPERATIONS ____ SAFETY

TYPE OR PRINT NAME	SIGNATURE	ORGN.	DATE
Malcolm Glenn	Malcolm Glenn	EI-C-A	2/18/99
LLOYD EDGECOMB	Lloyd Edgecomb	USA 5532	3/17/99
WALTER BOYTER	Walter C. Boyter	PK-H	4/12/99
JOHN W. GARRETT	John W. Garrett	USA 5451	4/20/99
A. M. STEVENS	A.M. Stevens	USA 5930	4/30/99

CONTRACTOR DIRECTOR OF SAFETY

OPERATION: Aft Booster Set Down on the Mobile Launch Platform Hold Down Posts Using 325-Ton Crane

SUPPORTING DOCUMENTS: The associated operational procedure/systems assurance analyses are as follows:

1. OMI B5303, Stacking and Alignment Operations.
2. SAA09FY120-001, System Assurance Analysis of the 325-Ton Bridge Cranes at the Vehicle Assembly Building (VAB).

GENERAL DESCRIPTION: Four personnel are required to be directly under the suspended aft booster assembly during aft booster positioning on the Mobile Launch Platform (MLP) Hold Down Posts (HDP). Operations include the following:

- Re-shim the HDP bearings to adjust aft skirt loading.
- Clean, inspect, and repair aft skirt shoe sockets.
- Align aft skirt shoes during set down operations.

The aft booster is connected to the H77-0384-3 lifting beam which is connected to the 325-ton bridge crane. The lifting beam can be connected to the 250-ton Delmar Hydra-set which would be connected to the 325-ton bridge crane. The hydra-set is not specifically used in this task but could be used for segment mate operations.

The aft booster is raised off the transportation pallet. The aft booster is then lifted to the high bay from the transfer aisle. There are no personnel under the suspended aft booster during lifting operations to the high bay. The aft booster is then positioned approximately 2 feet above the HDPs. The booster is held stationary until personnel can man-up on the MLP zero level.

The aft booster aft skirt shoe sockets are then inspected/repaired. The aft booster is then lowered to approximately 6-8 inches above the HDPs. A "pre-contact" recording is made of the HDPs strain gage readouts. The aft booster is then aligned and lowered onto the MLP HDPs. A "post-contact" recording is made of the HDPs strain gage readouts. The aft booster alignment operations require four personnel to be directly under the suspended aft booster.

Strain gages in the MLP HDPs are used to determine the loading into the aft skirt. If the strain gauges indicate the loading is outside the acceptable range, the bearings must be re-shimmed. To perform the bearing re-shimming, the aft booster is raised approximately 3 feet above the HDPs and held stationary. The bearings and shims are removed and the replacement shims are installed. The bearings are then repositioned on the HDPs. This operation requires four personnel to perform the bearing/shim change out while directly under the suspended aft booster.

After re-shimming, a "pre-contact" recording is made of the HDP strain gage readouts. The aft booster is then aligned and lowered onto the MLP HDPs. A "post-contact" recording is made of HDPs strain gage readouts. The aft booster alignment operations require four personnel to be directly under the suspended aft booster.

RATIONALE/ANALYSIS: The suspended load tasks comply with the NASA Alternate Safety Standard for Suspended Load Operations as follows:

Alternate Standard Requirement #1a: The operation cannot be performed without personnel beneath the suspended load because there are no operational means of performing the booster alignment without risking damage to flight hardware. By physically positioning a person under the aft booster, clearances required in the alignment are maintained. Design options to build an alignment tool increased the hazards associated with working under a suspended aft booster segment. The alignment tool would introduce a new suspended load operation. In addition, there is no feasible method of removing the bearing shims without physically being under the suspended booster that would not greatly impact booster processing or increase the hazards associated with the aft booster positioning on the MLP.

An inspection stand shoe adapter to perform inspections while supporting the aft booster assembly over the transportation pallet was investigated. The shoe adapter was determined to be unstable for protecting personnel under a suspended load. The adapter would have to be bolted to the support post ball fittings on the transportation pallet. The clearances required to prevent damage to the exit cone (approximately 6 feet above the floor of the transfer aisle to allow for nozzle clearance) prohibit the use of dunnage or any other stand. The proposed adapters, which would weigh a minimum of 400 pounds each, would require the assistance of a hoist or a mobile crane for installation on the transportation pallet. Installation of these adapters would be a suspended load operation.

No other tooling is available or feasible to support the weight of the entire aft booster assembly should a crane or lifting beam failure occur.

Alternate Standard Requirement #1b: Secondary support systems to assume support of (catch) the load were evaluated and were not feasible for this operation; see Alternate Standard Requirement #1a.

Alternate Standard Requirement #1c: The maximum number of personnel allowed under the suspended booster at any one time during aft booster alignment, hold down post bearing re-shimming or aft booster shoe dry-lube repair is four.

Alternate Standard Requirement #1d: Personnel will accomplish the required suspended load tasks as quickly and safely as possible to minimize time exposure. Total exposure time is approximately 30 minutes for alignment/positioning per HDP and 30 minutes per shoe for inspection and repair.

Alternate Standard Requirement #2: Suspended load operations are reviewed and approved on a case-by-case/specific need basis - see General Description and Alternate Standard Requirement #1.

Alternate Standard Requirement #3: Only those suspended load operations approved by the Center NASA Safety Assurance Director will be permitted. A list of approved suspended load operations will be maintained by the Center NASA Safety Assurance Directorate.

Alternate Standard Requirement #4: OMI B5303 is written to allow only required personnel under the suspended load. The OMI is available on site during the operation.

Alternate Standard Requirement #5: A new suspended load operation not covered by this SLOAA, deemed necessary due to unusual or unforeseen circumstances where real time action is required, shall be documented and approved by the Center NASA Safety Assurance Director.

Alternate Standard Requirement #6: Suspended load operations in the VAB associated with lifting motor segments involve the use of one of the 325-ton bridge cranes. The 325-ton bridge cranes are designed, tested, inspected, maintained, and operated in accordance with NSS/GO-1740.9, the NASA Safety Standard for Lifting Devices and Equipment. The cranes are designed with a minimum safety factor of 5 (based on the ultimate material strength) for the hoist load bearing components.

The cranes are equipped with redundant hoist drive systems (including hoist wire ropes and holding brakes) each capable of lifting and holding the load to the crane's rated capacity. The cranes have a dual braking system with overspeed braking. A load test is performed annually to 100 percent of the rated capacity of the crane.

The 325-ton cranes undergo a monthly, quarterly, semiannual, and annual preventive maintenance program. The wire rope is inspected monthly for discrepancies. The crane hook undergoes an annual Non-Destructive Testing (NDT) inspection.

The H77-0384-3 segment lifting beams were one-time proofloaded to 740,000 +/- 74,000 pounds and are load tested annually to 462,000 +/- 10,000 pounds. The beams also undergo a semiannual preventive maintenance and an annual NDT for load-bearing members and critical welds.

The lifting beams were designed to a 5 to 1 safety factor for failure and 3 to 1 for yield. The safe working load of the H77-0384-3 lifting beam is 370,000 pounds. The heaviest flight component lifted is the aft booster which weighs approximately 350,000 pounds.

The Delmar DHS 250 (vendor part number 16553) is a 250-ton hydra-set which can be used for stacking booster motor segments. The hydra-set underwent a one-time proof test of 1,000,000 +/- 10,000 pounds. for a minimum of 5 minutes. The 250-ton hydra-set also undergoes an annual load test of 625,000 pounds. A preventive maintenance program and a leak check are performed prior to the start of each flight motor set stacking operation. Prior to each use the hydra-set undergoes an operational check.

Alternate Standard Requirement #7: A System Assurance Analysis (SAA) has been completed on the VAB 325-ton bridge cranes. The SAA includes a Failure Modes and Effects Analysis/Critical Item List (FMEA/CIL) and a hazard analysis (see Supporting Documents).

The SAA for the 325-ton crane identifies 1 Single Failure Point (SFP), the Programmable Logic Controller (PLC). The PLC controls motion for the hoist, bridge and trolley. The identified failure mode is an unsolicited command from the PLC could initiate or continue a crane motion in an uncommanded direction or speed. The PLC is designed to industry standards and is UL listed. Internal diagnostics verify all crane controls each time the crane is used and crane control functional checks are performed before each use. The PLC is electrically isolated from external voltages/currents. Crane software was validated and extensively tested per the acceptance test procedure. If a failure were to occur, the crane operators can secure the load by applying brakes.

There is no history of failure with the SFPs in the critical failure mode. The use of high quality, reliable components and a comprehensive maintenance, inspection, and test program, including preoperational checks ensures that the crane systems operate properly. If a failure were to occur, it can be recognized by the selsyn position which is in view of both crane operators. The crane operators would secure the load by applying the brakes.

Emergency (E) stop operators, remote from the crane operator's cab, can stop the crane if a failure indication is observed.

The associated SAA CIL sheets identify the rationale for accepting the risk of the SFPs, including design information, failure history, and the operational controls in effect to minimize the risks (maintenance, inspection, test, etc.).

Alternate Standard Requirement #8: The 325-ton bridge crane undergoes a visual inspection and pre-operational checkout prior to each use per NSS/GO-1740.9.

Alternate Standard Requirement #9: A trained, licensed and certified operator will remain at the controls while personnel are under a suspended load. In addition, a qualified Emergency Stop operator is stationed in the vicinity of personnel working under the suspended load. All personnel responsible for the direction and/or performance of the operation undergo training that meets or exceeds the required certifications per NSS/GO-1740.9.

Alternate Standard Requirement #10: Control areas are established per OMI B5141. For solid rocket booster lifting operations, a control area is established in the high bay and adjacent transfer aisle. Only essential personnel are allowed in the control area. A second, smaller control area is established under a suspended load.

Control areas are established using rope, amber lights, and placards to ensure non-essential personnel are kept out of the area. For operations under a suspended load, a badge board is maintained in the immediate area. Only those personnel badged and with the approval of the Task Leader are allowed under the load.

Alternate Standard Requirement #11: Pre-operational briefings are held by the Task Leader and all essential personnel involved with the operation. Shift change pre-operational briefings are held if operations are to occur on multiple shifts.

Alternate Standard Requirement #12: Communications (by voice, radio and visual) are maintained with all personnel under a suspended load. Emergency procedures contain instructions and personnel are trained to discontinue operations if communications are lost. The hardware is safed and the area is cleared if additional hazards warrant clearing the control area. All personnel are cleared from under a suspended load during loss of communications.

Alternate Standard Requirement #13: All personnel remain within sight of the Lift Coordinator and the Emergency Stop operator.

Alternate Standard Requirement #14: The Center NASA Safety Assurance Directorate shall conduct periodic reviews to ensure the continued safety of suspended load procedures.

Alternate Standard Requirement #15: The Center NASA Safety Assurance Directorate will provide copies of approved SLOAAs, a list of approved suspended load operations, a list of cranes/hoists used for suspended load operations and copies of the associated FMEA/CIL and hazards analyses to NASA Headquarters.

OPERATION: Solid Rocket Motor Pre-Stack Operations Using 325-Ton Crane

SUPPORTING DOCUMENTS: The associated operational procedure/systems assurance analyses are as follows:

1. OMI B5303, Stacking and Alignment Operations.
2. SAA09FY120-001, System Assurance Analysis of the 325-Ton Bridge Cranes at the Vehicle Assembly Building (VAB).

GENERAL DESCRIPTION: A maximum of six personnel are required to be directly under the suspended solid rocket booster to support stacking operations.

- Install the V-2 volume filler in tang capture feature.
- Install o-ring in the tang capture feature o-ring groove.
- Remove corrosion and/or contamination from clevis and tang.
- Apply final grease application to tang and clevis bare metal.
- Abrade the clevis j-seal insulation prior to adhesive lay-up.
- Apply the joint adhesive to both the tang and clevis j-seal.
- Install o-ring in clevis o-ring grooves (2 each).
- Remove tape and masking from j-seal insulation.
- Photograph and video the clevis and tang.
- Measure the clevis gap prior to and after FJAF installation.
- Final 360 degree walk-down of field joint prior to mate.

The Redesigned Solid Rocket Motor (RSRM) segment is connected to the H77-0384-3 lifting beam which is connected to the 325-ton bridge crane. The lifting beam can be connected to the 250-ton Delmar Hydra-set which would be connected to the 325-ton bridge crane. The hydra-set can be used in this task to perform a demate of the RSRM segments.

The segment is raised off the segment transportation pallet. The segment is positioned in the transfer aisle for inspections of the tang metal part mating surfaces, tang j-seal abrading, and for installation of the joint enclosure used to prevent contamination of the field joint. The segment is then lifted to the high bay. The segment is positioned approximately 3 feet above the clevis of the segment below. The segment is held stationary until the personnel can man-up on the appropriate platform.

The segment is then lowered to position the tang end (aft) approximately 18 inches above the clevis of the segment to be mated. The tang is then aligned both axially and radially. The pre-stack preparations, operations, and inspections listed previously are all suspended load operations. Personnel are required to have their hands and arms under the suspended segment to perform these tasks.

RATIONALE/ANALYSIS: The suspended load tasks comply with the NASA Alternate Safety Standard for Suspended Load Operations as follows:

Alternate Standard Requirement #1a: The operation cannot be performed without personnel beneath the suspended load. There are no operational or designed means of performing the segment pre-stacking operations without risking damage to flight hardware or compromising the integrity of the field joint. By allowing personnel to position their hands and arms under the segment, they can verify the field joint was properly assembled and that all components were thoroughly inspected during installation. Design options evaluated to abate the suspended load increased the hazards associated with working under a suspended segment and day-to-day processing.

The addition of new tooling in the high bay would increase the everyday hazards associated with stacking operations. The additional tooling would increase the stacking time line (hence exposed propellant hazards) and risk of personal injury. Presently the following tooling is required to mate a segment:

Temposonics - a computer record of the mating segment's rate of engagement and parallelism. The device consists of four sensor rods connected by cables to a data acquisition system (DAS) and computer.

Field Joint Assembly Fixture (FJAF) - tooling designed to ensure proper clearances for the tang capture feature o-ring groove by "bear hugging" the outboard clevis leg. This reduces the likelihood of the barrier o-ring being cut during assembly. This piece of tooling is built in four 8-foot sections that rest on the clevis leg. Each piece is placed on the outer clevis leg by a minimum of two personnel.

Lifting Beam Console - provides real time display to assist engineering in monitoring stacking progress.

Hydra-set Console - console controls the 250-ton hydra-set used to perform the mating operations.

Should an incident occur, such as a propellant fire, the tooling used to prevent a segment from dropping in the event of a failure would add an additional obstacle in the event emergency egress is warranted. Additional tooling would also add to the everyday hazards associated with working on elevated platforms and increase potential tripping hazards.

Two design options were evaluated to abate the suspended load operation. One was to modify the access platforms and/or the entire high bay to support the 330,000 lbs. segment during the stacking operations. This did not seem physically possible without completely redesigning the VAB and no guarantees could be made that the stacking operation critical processes would not be affected. The access platforms are not able to support the weight of a segment. A complete redesign of High Bays 1 and 3 would be required.

The other option would be to develop tooling that would interface with the tang and the clevis of the two segments being mated. However, backup support of some unknown design concept could not be envisioned to maintain the dropped hardware in the vertical position. This option is not desirable as the integrity of the field joint would be greatly compromised. This would also require an additional inspection of the joint mating surfaces after the tooling was removed and would require operators to be under a suspended load.

Alternate Standard Requirement #1b: Secondary support systems to assume support of (catch) the load were evaluated and were not feasible for this operation; see Alternate Standard Requirement #1a.

Alternate Standard Requirement #1c: The maximum number of personnel directly under the suspended segment stacking operations is six.

Alternate Standard Requirement #1d: Personnel will accomplish the required suspended load tasks as quickly and safely as possible to minimize time exposure. Total exposure time is approximately 4 to 8 hours to complete all the preparation, inspection, and installation operations.

Alternate Standard Requirement #2: Suspended load operations are reviewed and approved on a case-by-case/specific need basis - see General Description and Alternate Standard Requirement #1.

Alternate Standard Requirement #3: Only those suspended load operations approved by the Center NASA Safety Assurance Director will be permitted. A list of approved suspended load operations will be maintained by the Center NASA Safety Assurance Directorate.

Alternate Standard Requirement #4: OMI B5303 is written to allow only required personnel under the suspended load. The OMI is available on site during the operation.

Alternate Standard Requirement #5: A new suspended load operation not covered by this SLOAA, deemed necessary due to unusual or unforeseen circumstances where real time action is required, shall be documented and approved by the Center NASA Safety Assurance Director.

Alternate Standard Requirement #6: Suspended load operations in the VAB associated with lifting motor segments involve the use of one of the 325-ton bridge cranes. The 325-ton bridge cranes are designed, tested, inspected, maintained, and operated in accordance with NSS/GO-1740.9, the NASA Safety Standard for Lifting Devices and Equipment. The cranes are designed with a minimum safety factor of 5 (based on the ultimate material strength) for the hoist load bearing components.

The cranes are equipped with redundant hoist drive systems (including hoist wire ropes and holding brakes) each capable of lifting and holding the load to the crane's rated capacity. The cranes have a dual braking system with overspeed braking. A load test is performed annually to 100 percent of the rated capacity of the crane.

The 325-ton cranes undergo a monthly, quarterly, semiannual, and annual preventive maintenance program. The wire rope is inspected monthly for discrepancies. The crane hook undergoes an annual Non-Destructive Testing (NDT) inspection.

The H77-0384-3 segment lifting beams were one-time proofloaded to 740,000 +/- 74,000 pounds and are load tested annually to 462,000 +/- 10,000 pounds. The beams also undergo a semiannual preventive maintenance and an annual NDT for load-bearing members and critical welds.

The lifting beams were designed to a 5 to 1 safety factor for failure and 3 to 1 for yield. The safe working load of the H77-0384-3 lifting beam is 370,000 pounds. The heaviest flight component lifted is the aft booster which weighs approximately 350,000 pounds.

The Delmar DHS 250 (vendor part number 16553) is a 250-ton hydra-set which can be used for stacking booster motor segments. The hydra-set underwent a one-time proof test of 1,000,000 +/- 10,000 pounds for a minimum of 5 minutes. The 250-ton hydra-set also undergoes an annual load test of 625,000 pounds. A preventive maintenance program and a leak check are performed prior to the start of each flight motor set stacking operation. Prior to each use the hydra-set undergoes an operational check.

Alternate Standard Requirement #7: A System Assurance Analysis (SAA) has been completed on the VAB 325-ton bridge cranes. The SAA includes a Failure Modes and Effects Analysis/Critical Item List (FMEA/CIL) and a hazard analysis (see Supporting Documents).

The SAA for the 325-ton crane identifies 1 Single Failure Point (SFP), the Programmable Logic Controller (PLC). The PLC controls motion for the hoist, bridge and trolley. The identified failure mode is an unsolicited command from the PLC could initiate or continue a crane motion in an uncommanded direction or speed. The PLC is designed to industry standards and is UL listed. Internal diagnostics verify all crane controls each time the crane is used and crane control functional checks are performed before each use. The PLC is electrically isolated from external voltages/currents. Crane software was validated and extensively tested per the acceptance test procedure. If a failure were to occur, the crane operators can secure the load by applying brakes.

There is no history of failure with the SFPs in the critical failure mode. The use of high quality, reliable components and a comprehensive maintenance, inspection, and test program, including preoperational checks ensures that the crane systems operate properly. If a failure were to occur, it can be recognized by the selsyn position which is in view of both crane operators. The crane operators would secure the load by applying the brakes.

Emergency (E) stop operators, remote from the crane operator's cab, can stop the crane if a failure indication is observed.

The associated SAA CIL sheets identify the rationale for accepting the risk of the SFPs, including design information, failure history, and the operational controls in effect to minimize the risks (maintenance, inspection, test, etc.).

Alternate Standard Requirement #8: The 325-ton bridge crane undergoes a visual inspection and pre-operational checkout prior to each use per NSS/GO-1740.9.

Alternate Standard Requirement #9: A trained, licensed and certified operator will remain at the controls while personnel are under a suspended load. In addition, a qualified Emergency Stop operator is stationed in the vicinity of personnel working under the suspended load. All personnel responsible for the direction and/or performance of the operation undergo training that meets or exceeds the required certifications per NSS/GO-1740.9.

Alternate Standard Requirement #10: Control areas are established per OMI B5303. For solid rocket booster lifting operations, a control area is established in the high bay and adjacent transfer aisle. Only essential personnel are allowed in the control area. A second, smaller control area is established under a suspended load.

Control areas are established using rope, amber lights, and placards to ensure non-essential personnel are kept out of the area. For operations under a suspended load, a badge board is maintained in the immediate area. Only those personnel badged and with the approval of the Task Leader are allowed under the load.

Alternate Standard Requirement #11: Pre-operational briefings are held by the Task Leader and all essential personnel involved with the operation. Shift change pre-operational briefings are held if operations are to occur on multiple shifts.

Alternate Standard Requirement #12: Communications (by voice, radio and visual) are maintained with all personnel under a suspended load. Emergency procedures contain instructions and personnel are trained to discontinue operations if communications are lost. The hardware is safed and the area is cleared if additional hazards warrant clearing the control area. All personnel are cleared from under a suspended load during loss of communications.

Alternate Standard Requirement #13: All personnel remain within sight of the Lift Coordinator and the Emergency Stop operator.

Alternate Standard Requirement #14: The Center NASA Safety Assurance Directorate shall conduct periodic reviews to ensure the continued safety of suspended load procedures.

Alternate Standard Requirement #15: The Center NASA Safety Assurance Directorate will provide copies of approved SLOAAs, a list of approved suspended load operations, a list of cranes/hoists used for suspended load operations and copies of the associated FMEA/CIL and hazards analyses to NASA Headquarters.

APPROVAL: DATE:

Malcolm Glenn for 4/28/99
Bruce L. Jansen
Acting Director, Safety Assurance
Kennedy Space Center